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PULSE CROP GERMPLASM DEVELOPMENT INITIATIVE FOR SASKATCHEWAN - PHASE II

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Pulse Crop Germplasm Development Initiative for Saskatchewan – Phase II

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Abstract

The focus of this research project was on the development of new germplasm streams for the dry bean, lentil, chickpea and field pea breeding programs for eventual development of improved varieties of these crops for Saskatchewan pulse crop growers.

For dry bean we developed adapted breeding lines in several new market classes that may some day be produced for export. The most promising types are the yellow, flor de mayo, flor de junio and carioca classes. We also developed breeding populations that incorporated genes for resistance to two major diseases of beans, sclerotinia and halo blight.

In chickpea, we introduced the sources for ascochyta resistance and introduced a breeding stream designed to help develop varieties with resistance to botrytis grey mould. A third objective was the development of a breeding strategy involving improvement of tolerance to cold temperatures.

Development of improved tolerance to three major world diseases was the focus of the pea sector of this project. We developed breeding populations, collaborative research strategies and screening nursery access for Mycosphaerella blight, Fusarium wilt and Aphanomyces root rot

The lentil germplasm development strategy was based on developing breeding strategies and international collaborations focused on resistance to three new diseases of lentil in Saskatchewan, botrytis, sclerotinia and stemphylium. We developed breeding lines and genetic stocks for future research with improved tolerance against these diseases.

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1 Background

This project was focused on the future germplasm requirements for breeding programs for existing pulse crops in Saskatchewan and western Canada. This type of research and development activity is crucial to the future expansion of the pulse industry through diversification of pulse products and through improvement of quality and productivity.

The objective of the project was to accelerate development of pulse crop germplasm (dry bean, chickpea, field pea and lentil) for selected traits. Progress through conventional breeding for these traits is difficult and each requires special emphasis through development of specific long-term germplasm improvement. In order for future pulse breeding programs to become and remain competitive on a global scale, germplasm development must be pro-active. This will assist the Saskatchewan pulse industry reach and maintain a leading position in the production, processing and export of the four major pulse crops. The major areas of germplasm development are improved disease resistance, improved adaptation and improved marketing characteristics.

2. Technical Report

The project was conducted as a series of crop specific sub-projects, each with specific goals and objectives. Progress to date is described below for each crop and sub-project

2.1 Dry bean

2.1.1 Adaptation of Market Classes for Mexico, Europe and Brazil

Crosses have been made to develop adapted germplasm for the following markets and bean classes:

Mexico	- flor de mayo, flor de junio, peruano, bayo
Brazil	- carioca, jalo
Colombia	- bola roja
Europe	- cranberry

During the project period, 8 crossing cycles were completed. Breeding for adaptation to Saskatchewan is a complex procedure involving multiparent crossing schemes and simultaneous selection for both market quality and early maturity. Parents were selected for recurrent crossing from early generation segregating population. F_1 seeds and F_2 populations were grown in the greenhouse in winter cycles and in the field in summer

cycles. The earliest maturing plants from well-adapted populations were selected for quality evaluation and use as recurrent parents. Selections were made in consultation with bean marketing companies, in consultation with overseas buyers during visits to the breeding program (for example, a CIGI pulse buyers program in 2004) and by on site consultation with bean importers and growers in Mexico at the Canada-Mexico Bean Congress in 2004.

In general, greenhouse cycles were successful. The 2003 field season was hot and dry and provided good screening conditions for all but the poorly adapted large-seeded types such as bola roja and cranberry. The 2004 field season, however, was useful only for extreme selection pressure for early maturity in all market classes. Some nurseries were affected by a severe hailstorm in July, followed by a mid-August frost. Nurseries designed to test yield potential were not successful.

Second generation bola roja types crossed with small red parents were field screened at the F_2 generation for adaptation Most plants were photoperiod sensitive, but flowers of the earliest flowering segregants were used to cross back to the original parental types to introduce genes for early maturity and maintenance of the large round red seed type. We expect that at least one more round of congruity backcrossing will be required. The 2004 season resulted in extreme selection pressure. We expect to have made good progress for early maturity, but to date we will not be successful in recovering large seed size. We do, however, now have a unique germplasm base for round-seeded beans. This will be of future value in breeding plump beans for many of the other market classes. Consultations with Mexican bean growers and marketers in 2004 confirmed that round beans are highly prized by consumers because of their fast-cooking qualities. We have informally confirmed this in our laboratory.

We have made good progress in developing early maturing lines in the bayo class because of their compatibility for genetic improvement with pinto beans. We have numerous advanced lines with early maturity and both determinate and indeterminate growth habit. The market status of this type is uncertain because it is considered to be in decline in Mexico. Trade and currency boundaries will likely be the largest influence on the future prospect for this type of bean.

Advanced lines of early-maturing lines of carioca and flor de mayo were selected during each cycle of inddor and outdoor selection for improved seed type, canopy type and yield to use as parents in compatible crosses with superior genotypes in existing market classes. Several were advanced to elite level testing in 2004. Two flor de mayo lines and one carioca were advanced to the Short Season Narrow Row Dry Bean Co-operative Trial in 2004. Only two sites reported valid yield data, but at both locations, yield levels were acceptable in comparison to check cultivars in other market classes. One of the flor de mayo lines is particularly interesting because it has the same growth and maturity characteristics as CDC Pintium, the most successful Saskatchewan-bred bean variety to date.

The first determinate early-maturing flor de junio plants were selected in the field in 2004. Seed samples were shown to Mexican buyers and seed type was considered to be within the range of acceptable market characteristics. Further selection for plump shape will be necessary to match long-term market expectations.

About 100 F2-derived F3 yellow bean lines (both round and tubular types) were grown in microplots in 2003. The best-adapted progenies were harvested for use as parents but some were advanced for further evaluation. The first yellow bean lines were entered in preliminary trials in 2004 but the combination of hail and frost prevented effective selection. Nevertheless, selection for earliness for recurrent selection was possible. Seed type was evaluated in Mexico City and Guadalajara in December 2004. Knowledgeable buyers indicated that both the tubular and round yellows were acceptable, indicating that our selection criteria match market expectations. At this stage we consider the Brazilian jalo class to intergrade with the tubular versions of the Mexican yellow bean classes, so our progress to date is similar. Canadian bean exporters are now developing a keen interest in this market class and potential exists for future commercial application.

One of the key objectives is maintenance or improvement of seed coat quality in all market classes. A slow-darkening pinto bean line was used to introduce variability for improved quality in compatible market classes. We made F_2 field selections of slow-darkening carioca types in summer of 2003 and continued selection for other characters in 2004. We confirmed that the slow-darkening gene is effective in the carioca class. Introduction of this trait may generate interest in Brazilian markets based on feedback received from Brazilian pulse importers in the summer of 2004. Our results also showed that this gene may not work for other market classes with colour retention problems (flor de mayo and flor de junio) because it prevents pink colour deposition in the seedcoat.

2.1.2 Halo Blight Resistance

At the beginning of this project, Dr. Sabine Banniza initiated correspondence with researchers in the UK where the diagnostic set of isolates for the various races of halo blight are maintained. Cultures of 6 of the 9 races described to date were first received in the winter of 2002. A protocol for the routine screening of halo blight was developed involving point inoculation of the strains into the bean pods. The three additional isolates were obtained in spring 2004 from the UK.

We have also continued our collaboration with with bean geneticist Dr. Phil Miklas of USDA Prosser in Washington State. In the summer of 2002, a research project involving development of halo blight resistance and molecular markers was initiated in collaboration with a bean pathology group from South Africa. We have started correspondence with them on how best to integrate our efforts with theirs to avoid duplication. Our potential collaboration will involve developing AFLP markers for populations now being developed at USDA.

Discussions on the status of the work were held in conjunction with the Bean Improvement Co-operative biennial meeting in Sacramento in October, 2003. Marker work for the halo blight resistance genes will commence when all diagnostic RIL populations will be ready in Dr. Miklas' laboratory. The populations were phenotyped for halo bight resistance in South Africa in the fall of 2004. These populations were ready for further development of markers at the end of 2004. We will begin screening for linked molecular markers beginning in spring of 2005.

Halo blight isolates representing the Canadian production areas are now being collected by Dr. Banniza and her colleagues at AAFC Morden and other research centres. This work will be continued as part of a new NSERC Collaborative Research and Development project coordinated by Pulse Canada.; It includes participants from all provincial bean producer groups with specific focus on genetic improvement of resistance to common and halo blight.

2.1.3 White Mold Resistance

We made crosses with navy bean germplasm from Dr. Soon Park's breeding program in Ontario. Improved white mold tolerance has been one of the objectives in his breeding program for a number of years. Several US bean breeding and pathology groups are working on white mold, trying to improve genetic resistance and to improve screening methodology. We are monitoring the progress of indoor screening techniques for while mold in dry bean as part of USDA's Sclerotinia Initiative.

We have also made crosses with various breeding lines developed in US public breeding programs for sources of white mold resistance in various backgrounds. Crosses were made with advanced lines developed by Michigan State University and by the USDA at Prosser, Washington. The first F_2 populations were available for field screening in the summer of 2004. Selection conditions for earliness were extreme and may have been too severe to capture the genetic combination of early maturity and while mold resistance. Our future plan in this regard is to establish a white mold nursery using new irrigation facilities scheduled for installation in the spring of 2005. Surviving material will be screened in this nursery once sufficient seed supplies are recovered.

2.2 Chickpea

2.2.1 Introgressing New Sources of Ascochyta Blight Resistance for Kabuli Chickpea

Annual exchange of germplasm with Australia and USA has been ongoing for the past three years. In general, the germplasm from the USA has lower levels of ascochtya resistance compared to current CDC breeding lines, while the Australian material has similar levels of resistance. Annual testing and crossing of new breeding lines from ICARDA and ICRISAT has also been ongoing.

A systematic genetic study is in progress evaluating allelism of four moderately resistant varieties from diverse sources. This is part of ADF/SPG project 20020160 and BRE0304, respectively. A series of F_2 populations from crosses between a susceptible (S) line x moderately resistant (MR) varieties were evaluated for AB reaction in the greenhouse and in the field in Saskatoon in 2004. Results from these analyses will be used to deduce the inheritance of the resistance gene(s) in these varieties. In addition, a set of F_2 populations derived from MR x MR crosses are under investigation, as well as several F_2 populations derived from crosses between MR germplasm introduced from ICARDA and ICRISAT. Preliminary results suggested that it is possible to increase the level of resistance to AB by intercrossing among selected resistant sources. New sources for resistance to AB were assessed from the annual and perennial wild species. A slightly higher level of resistance was identified in the annual wild species *C. bijugum* and *C. judaicum*. Plantlets have been recovered from the rescued-embryos of interspecific hybridization between these species and a cultivated variety. Tissue culture protocols need to be refined to convert the plantlets into normal plants. Screening of wild species will be expanded to include several perennial species.

Annual evaluation of CDC breeding lines at ICARDA has been useful in confirming and broadening the Saskatchewan results. This research is being conducted as part of ADF project 20000219.

Progress is being made in improving ascochyta blight resistance in the CDC breeding program. The kabuli cultivar CDC Frontier was released in 2003 and has resistance as good as any North American or Australian cultivar. The majority of breeding lines in the CDC program now have resistance at or near the level of CDC Frontier. However, CDC Frontier has late maturity in cool wet seasons like 2004. Many new breeding lines have similar ascochyta resistance as CDC Frontier, but with earlier maturity in the range of earlier maturing checks such as Amit and CDC Xena. CDC Frontier has approximately 8 mm seed size. Market premiums are commanded by kabuli varieties with larger seed size. Our current emphasis is on selecting lines with the ascochyta blight resistance of CDC Frontier, with earlier maturity and larger seed size. Lines with fitting these criteria are now reaching the Saskatchewan regional trial level.

2.2.2 Development of Adapted Germplasm with Botrytis Tolerance

Since ascochyta blight is by far the key disease problem in chickpea in Saskatchewan it has received the most attention in the breeding program. Botrytis is a disease of moderate importance in the wetter areas of chickpea production in India and Bangladesh. We have accessed some of this germplasm through our collaboration with ICRISAT. In the near future we expect to receive new germplasm with improved botrytis tolerance from the chickpea program at Punjab Agricultural University at Ludhiana through our collaboration with ICRISAT. This program has been conducting research on ascochyta blight and botrytis grey mold for the past 20+ years and has made good progress on both diseases.

2.2.3 Development of Cold Tolerant Chickpea Germplasm

Through interaction with the chickpea breeding program at ICARDA, we are tapping into germplasm that has been specifically bred for adaptation to the West Asian highlands in Turkey and Iran. We regularly grow the ICARDA Chickpea International Cold Tolerance Nursery and the Chickpea International Drought Tolerance Nursery. Both trials produced several lines with good yield under drought conditions in 2003. These were further tested in 2004 preliminary yield trials at Saskatoon and Kyle. Again, several of these lines had good yield and will enter more extensive multi-location yield trials in 2005, for potential release as varieties in the future. Fortunately, most of these lines have 8-9 mm seed size with normal shape and attractive colour.

2.3 Field Pea

2.3.1 Continued Development of an Improved Germplasm Base for Mycosphaerella Tolerance

We continue to exchange advanced field pea breeding lines with co-operating breeding programs in the USA and Australia. Both programs have relatively strong emphasis on increasing mycosphaerella blight resistance. Breeding lines from USA and Australia are evaluated under field conditions in Saskatoon. Promising lines are used as parents in the crossing program. Informal germplasm exchange with several European pea breeders is also ongoing. Although breeding for disease resistance in general and mycosphaerella blight in particular is not a major emphasis for European breeders since routine fungicide use is quite common in Europe, access to their new higher yielding cultivars is beneficial in the long run.

In 2004, Dr. Warkentin, Dr. Sabine Banniza and Dr. Axel Diederichsen travelled to Russia and Ukraine on behalf of Pulse Canada. Excellent contacts were made at the N. I. Vavilov Institute (VIR), St. Petersburg, Russia and at the National Centre for Genetic Resources of Ukraine (NCGRU), Kharkiv, Ukraine. Limited germplasm exchanges have occurred with both institutes thus far, and expanded systematic exchanges could follow in the near future. We anticipate the opportunity to evaluate germplasm that has not previously been tested extensively in Canada or western Europe. Since both countries have a long history of pea production, we expect to identify lines with various beneficial traits including improved resistance to mycosphaerella blight.

In 2004 we also strengthened our collaboration with the pea genetics and pathology research group at INRA, Rennes, France. This is the leading pea mycosphaerella blight research group internationally. We planned joint research projects when we met at the European Grain Legume Research conference in Dijon, France in June 2004. Drs. Tivoli and Baranger then attended the Canadian Pulse Research Workshop in London, Ontario in December, 2004. We plan to exchange improved breeding lines and mycosphaerella isolates for mutual evaluation. In addition, both groups have made progress in molecular

mapping of genes for partial resistance to this disease. We hope to consolidate these maps with those developed by Dr. Timmerman Vaughn in New Zealand.

Drought conditions experienced in 2001-2003 generally reduced the severity of mycosphaerella blight in our breeding nurseries. Despite these unfavourable conditions for disease development, some level of selection pressure is present in each season since in our cropping rotation pea plots are usually situated less than 500 m from the previous season's pea trials. Based on experience at the Outlook irrigated site during the dry periods, it is possible to develop screening nurseries under irrigation, even in drought years. In 2004, the cool, moist conditions allowed for more intense selection for greater mycosphaerella blight resistance. CDC lines continue to rank among the better lines in terms of mycosphaerella blight ratings in the Field Pea Co-operative Test.

We anticipate gaining access to irrigated land in 2005 for specific disease nurseries. This will allow for application of moderately high disease pressure for mycosphaerella blight. We plan to use these nurseries to test specific populations for which improved resistance is the key goal. We would also test pre-breeder sub-lines for mycosphaerella blight resistance under irrigation.

2.3.2 Development of Germplasm with Improved Resistance to Fusarium wilt

Fusarium wilt is currently considerd to be relatively minor diseases in most of the pea growing regions of Saskatchewan. They are of greater importance in wetter regions including southern Manitoba and central Alberta. We expect that as the pea crop continues to expand and become regularly established in crop rotations, some specific regions with specific soil types will emerge as hot spots for these diseases.

Dr. John Kraft of USDA supplied nurseries of breeding lines with improved resistance to several important pea diseases including Fusarium wilt. A total of 140 lines were increased in the summer of 2002. In 2003 and 2004, the most promising lines were evaluated in replicated trials in Saskatoon or Rosthern under relatively low disease pressure. In general, these lines were lower yielding than CDC breeding lines and check cultivars under these conditions, but may be evaluated in more detail under irrigation in the future.

Dr. Kevin McPhee continued to screen the most advanced CDC pea breeding lines in the Fusarium nursery in Pullman, Washington as part of our germplasm exchange. In 2003 and 2004, most CDC lines were assessed as resistant or segregating for resistance to Fusarium wilt race 1. CDC lines continue to rank among the better lines in terms of Fusarium wilt ratings in the Field Pea Co-operative Test.

2.3.3 Development of Improved Tolerance to Aphanomyces

Aphanomyces root rot is considered a major soil borne disease of pea in parts of the world with a long history of production of pea crops, for example, the northern plains of France and the vegetable pea processing regions of the United States.
Many of the lines in the Kraft collection were rated as having improved levels of resistance to aphanomyces root rot. In 2003, 28 promising lines were evaluated in a four replicate trial in the AAFC Morden aphanomyces nursery in collaboration with Dr. Bob Conner. Under high disease pressure, several of the test lines had aphanomyces root rot severity lower than that of the check varieties CDC Mozart, Eclipse and Nitouche.

The INRA, Rennes group are also leaders in research on Aphanomyces root rot. We anticipate some collaboration on this topic also, although it will be a lower priority than mycosphaerella blight.

2.4 Lentil

2.4.1 Botrytis Gray Mold Resistance

Mark Kuchuran, an M.Sc. student, continued his work on characterizing botrytis gray mold BGM reactions of Canadian lentil varieties. Much of his work has been presented at workshops and conferences in 2003 and 2004. His studies confirm that many Canadian lentil varieties have improved levels of tolerance to BGM compared to those from the Middle East. Field-based evaluation of a number of lentil genotypes consistently showed that ILL 5588, known as Northfield in Australia, is highly susceptible to botryris gray mold (BGM). Some varieties like CDC Redcap and CDC Robin show much higher levels of tolerance to BGM.

Our collaborations on this topic with Australian researchers continued. Dr. Michael Materne of Horsham visited the breeding program at Saskatoon in 2003. We have received seed of the most tolerant selections in the Australian nurseries. Kurt Linbeck in Australia has developed a system for large-scale indoor screening of BGM for lentil. We are monitoring progress of this system and will consider developing a similar system if if proves to be effective.

Lines from Australia are poorly adapted and we initiated a three-way crossing program to introduce improved BGM tolerance. The first populations reached the field in F2 and F3 nurseries in 2004. Conditions were excellent for development of late season BGM, however, all lentil nurseries were also affected by other late season canopy disease such as sclerotinia and stemphylium.

We expect to be able to use existing RIL populations to characterize tolerance and possibly develop molecular markers. A reliable indoor screening technique for BGM is still under development. We may use a modified method based on BGM screening methods used for faba bean in Australia.

In fall of 2004 we developed a collaboration with the ICARDA lentil breeding program and the Bangladesh Agricutlural Research Institute (BARI). BARI conducts a chickpea botrytis screening nursery in collaboration with Australia researchers. We were able to establish a lentil botrytis screening nursery adjacent to the chickpea area. These plots were seeded in late 2004 and we expect results will be available in spring of 2005. If this proves to be effective we will expand our collaborative effort on lentil BGM improvement next year.

2.4.2 Stemphylium Resistance in Lentil

In 2003, we initiated development of a laboratory screening technique for stemphylium. A graduate student, Mr. Pramod Kumar is working on this project. With assistance from Dr. Banniza's laboratory, methods for spore production and inoculation were completed in 2004. The first genetic characterization of resistance of parental lines was successfully completed and presented at the 5th Canadian Pulse Crop Research Workshop in London, 2004 and at Pulse Days 2005. We were able to clearly separate two groups of genotypes into those that were highly susceptible to stemphylium blight, and those that were more tolerant based on slow development of disease symptoms. Interestingly, our results show that CDC Milestone is in the susceptible group, while Eston is in the tolerant group. This result parallels anecdotal evidence from lentil growers in the Regina plain over the past 5 years.

We have made excellent progress developing populations for genetic analysis of resistance. Dr. Ashutosh Sarker has also supplied genetic material for this research and he began to work on aspects of this particular biotic constraint during his 3-month sabbatical period at Saskatoon, starting in August, 2004. Dr. Sarker was able to develop a collaboration on our behalf with the Bangladesh Agricultural Research Institute (BARI) at Ishurdi, Bangladesh, on our behalf. A set of diagnostic parents developed from indoor experiments and a set of 90 F6-derived recombinant inbred lines were seeded in November for field screening for stemphylium blight in January-February 2005. The first ratings of this nursery were recorded by Mr. Pramod Kumar, an M.Sc. candidate, during a visit to Bangladesh in early January 2005.

2.43 Improvement of Sclerotinia Resistance in Lentil

Crossing and development of segregating populations began in the summer of 2002. This has continued and several populations are now available for characterization in the field. ICARDA lentil breeder, Dr. Ashutosh Sarker and Dr. Fred Muehlbauer have identified additional sources of resistance and Dr. Weidong Chen at USDA has developed techniques for screening. . Dr. Muehlbauer's group has identified CDC Sovereign as a source of resistance to sclerotinia based on 2 years of observation in the Palouse. In fact it was rated as the most resistant genotype in those investigations. This is particularly interesting because our own field and greenhouse observations indicate that CDC Sovereign has a stiffer stem. At our screening nursery at Rosthern in 2004, we were able to screen many lines for sclerotinia tolerance. Significant differences in reaction were reported in many replicated trials. CDC Redberry and other small red lines such as 1194-

3 and 1194-67 were significantly better for % sclerotinia infection (10-15% range) compared to standard cultivars that scored in the 50% range.

RIL population development methods have been modified in our greenhouse facilities, allowing us to rapidly produce large numbers of small lentil plants for single seed descent population increases. We have rapidly developed populations for characterization of genetic interactions with sclerotinia. Dr. Sarker has also supplied "stiff stem" populations that may prove useful in breeding for sclerotinia resistance. In the next year we will combine all components of this sub-project to develop a system for indoor and field screening. We have obtained solid evidence of genetic differences in reaction and intend to pursue this area of research more vigorously because red lentil production is likely to expand into regions of the province where this disease may be more likely to become a problem. We have supplied Dr. Chen with seed samples of all parents of all RIL populations for sclerotinia resistance assessment so that we can take advantage of any existing populations in future studies.

2.4 **Conclusions**

Most of the effort in this project went toward establishing a genetic base to underpin future improvement efforts for specific disease resistance traits or quality traits in dry bean, chickpea, lentil and field pea. In almost all cases, we have (1) observed direct evidence of improvements in the genetic base populations, (2) developed collaborations that will help us achieve genetic improvements in the near future through improved germplasm access or improved screening techniques, or (3) been able to develop breeding populations that will enable us to conduct the necessary future genetic studies that will allow us to develop appropriate breeding strategies. Specific conclusions based on progess to date are listed below.

2.5.1 We have made good progress in developing adapted lines for most of the various market classes of dry bean. Some are now included in national level registration trials. These can now form the basis of future breeding efforts. Market research indicates that these lines are now in the range of commercial acceptability, and we are receiving enquiries about commercialization options for some of the market classes.

2.5.2 We have developed collaborations with researchers in the USA and South Africa that will enable us to efficiently screen for halo blight resistance in our parental germplasm for bean breeding by 2006.

2.5.3 Genetic resources for improved white mold tolerance have been incorporated into segregating populations in several dry bean market classes. Selection for early maturity is in progress. Field and greenhouse screening capability will be enhanced by investment in new lab techniques and irrigation capability in 2005.

2.5.4 Kabuli chickpea germplasm with resistance to ascochyta blight from most of the world's major chickpea breeding centres has been used in crosses with locally adapted varieties.

2.5.5 We have established germplasm exchanges with Indian chickpea breeding programs focused on botrytis grey mold resistance breeding.

2.5.6 Cold tolerant germplasm has been introduced into the genetic base of the CDC chickpea breeding program.

2.5.7 We have introduced new germplasm with improved levels of botrytis resistance into the lentil breeding program, and have successfully developed collaborations on this topic with researchers in Australia and Bangladesh.

2.5.8 We have introduced lentil germplasm with improved tolerance to stemphylium blight in the breeding program, and have also developed a research base to proceed with genetic studies and screening methods, both indoors and through international collaborations in Bangladesh.

2.5.9 We have developed lentil populations with improved levels of sclerotinia tolerance, and also demonstrated that some advanced breeding lines are available with improved sclerotinia tolerance. Genetic studies and screening methods are initiated.

2.5.10 Collaborations were developed for germplasm exchange and development of improved screening methods for field pea with research groups in Ukraine, France and Australia.

2.5.11 Successful screening nurseries were developed in collaboration with US researchers for Fusarium wilt of field pea.

2.5.12 Aphanomyces root rot screening procedures were initiated as part of this project in collaboration with AAFC Morden and new sources of improved tolerance were identified.

2.6 Personnel

To be supplied by U of S.

2.7 Equipment

No equipment was purchased.

2.8 Project Developed Materials

Various research posters related to many aspects of this project are available for viewing online at www.pulse.usask.ca. The links can be followed to posters and presentations at the 5th Canadian Pulse Research Workshop, at Pulse Days 2003, Pulse Days 2004 and Pulse Days 2005.

2.9 Project Photos

Project photos were used in poster preparations. These and other digital images of field and laboratory work are available on request.

2.10 Acknowledgements

Support for this project was described at the Pulse Crop Research Chair advisory board

meeting held in January 2004. This contribution to research funding was also highlighted at numerous extension presentations and field days in 2003 and 2004.

Several posters on bean quality and new market classes were presented at Pulse Days 2003, 2004 and 2005 and also at the 5th Canadian Pulse Crop Research Workshop in London, Ontario in December 2004. ADF funding was prominently acknowledged as part of all displays and presentations.

Posters and presentations on some of the work on BGM of lentil were presented at Pulse Days 2003 and at the 2003 NAPIA meeting by Mark Kuchuran, M. Sc. Student. ADF funding for this project was acknowledged. This presentation won a student prize at the NAPIA meeting.

Work on stemphylium research in lentil was presented jointly in poster form at Pulse Days 2003 by Mr. Pramod Kumar and Mr. Edmore Mwakutuya.

Many of the long term objectives of each segment of this project were presented in various forms at pulse crop extension meetings held each January and February in 2003, 2004 and 2005.